

Update on DVCS

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EIC Task Force meeting
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MILOU

Written by E. Perez, L Schoeffel, L. Favart [arXiv:hep-ph/0411389v1]

The code MILOU is Based on a GPDs convolution model by:

A. Freund and M. McDermott [All ref.s in: <http://durpdg.dur.ac.uk/hepdata/dvcs.html>]

- ✓ GPDs, evolved at NLO by an independent code which provides tables of CFF
 - at LO, the CFFs are just a convolution of GPDs:

$$\mathcal{H}(\xi, Q^2, t) = \sum_{u,d,s} \int_{-1}^1 \left[\frac{e_i^2}{1 - x/\xi - i\epsilon} \pm \{\xi \rightarrow -\xi\} \right] H_i(x, \xi, Q^2, t) dx$$

- ✓ provide the real and imaginary parts of Compton form factors (CFFs), used to calculate cross sections for DVCS and DVCS-BH interference.

$$\frac{d\sigma}{dx dy d|t| d\phi d\varphi} = \frac{\alpha^3 x_B y}{16\pi^2 Q^2 \sqrt{1+\epsilon^2}} \left| \frac{I}{e^3} \right|$$

$$\phi = \phi_N - \phi_l$$

$$\varphi = \Phi_T - \phi_N$$

$$\epsilon \equiv 2x \frac{m_N}{Q}$$

$$|I_{BH}|^2 = \frac{e^6}{x^2 y^2 (1+\epsilon^2)^2 \Delta^2 \mathcal{P}_1(\phi) \mathcal{P}_2(\phi)} \left\{ c_0^{BH} + \sum_{n=1}^2 c_n^{BH} \cos(n\phi) + s_1^{BH} \sin(\phi) \right\}$$

$$|I_{DVCS}|^2 = \frac{e^6}{y^2 Q^2} \left\{ c_0^{DVCS} + \sum_{n=1}^2 [c_n^{DVCS} \cos(n\phi) + s_n^{DVCS} \sin(n\phi)] \right\}$$

$$|I|^2 = \frac{\pm e^6}{xy^3 \Delta^2 \mathcal{P}_1(\phi) \mathcal{P}_2(\phi)} \left\{ c_0^I + \sum_{n=1}^3 c_n^I \cos(n\phi) + s_1^I \sin(\phi) \right\}$$

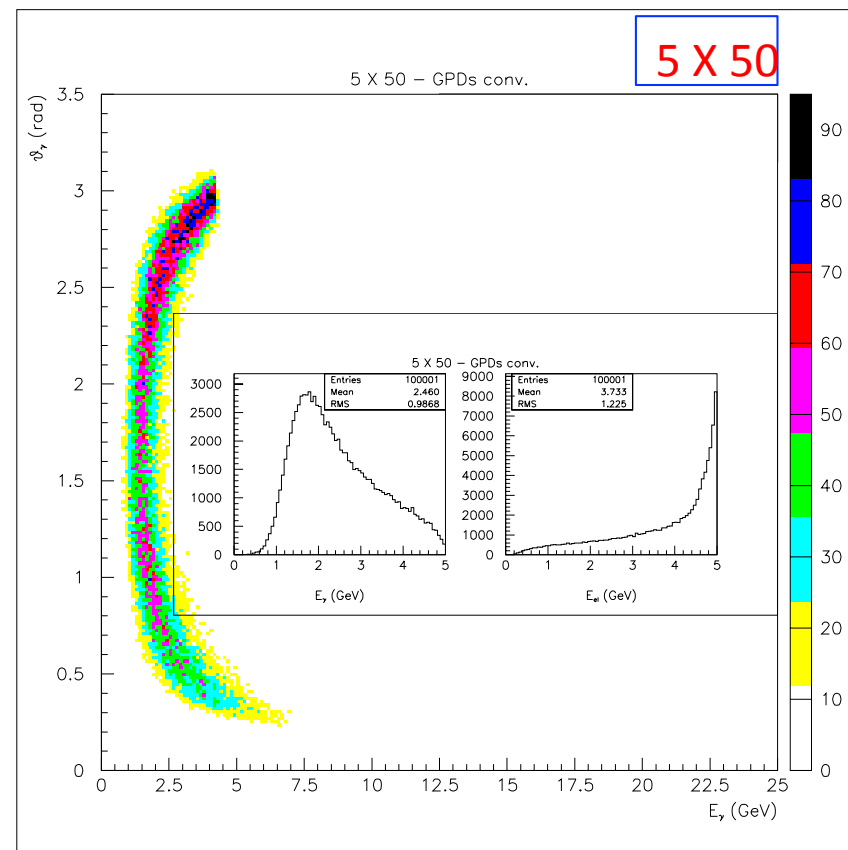
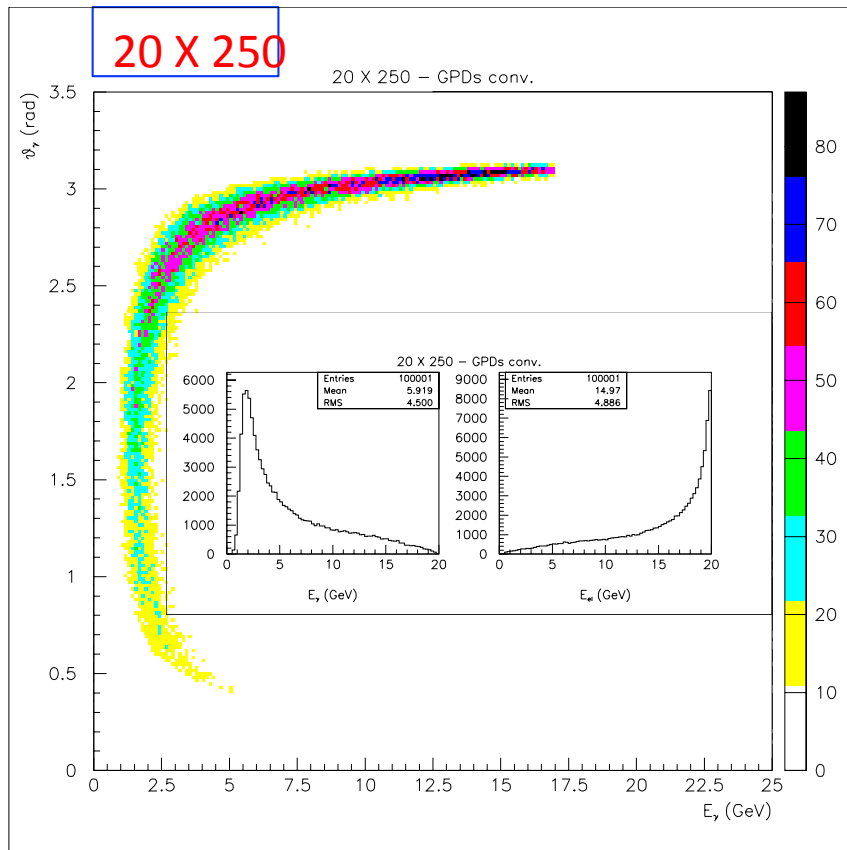
- ✓ $\frac{d\sigma}{d|t|} = \exp(B(Q^2)t) \rightarrow$ The B slope is allowed to be constant or to vary with Q^2 :

- ✓ Proton dissociation ($ep \rightarrow e \gamma Y$) can be included

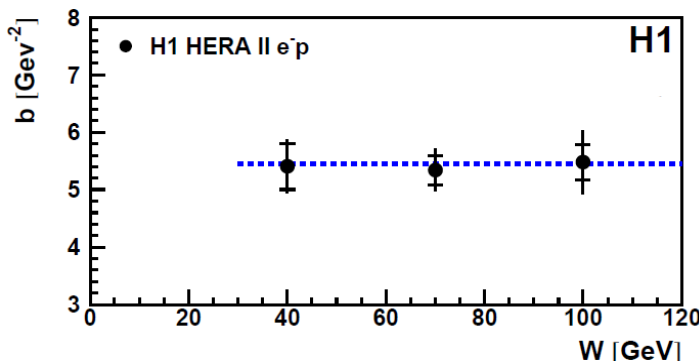
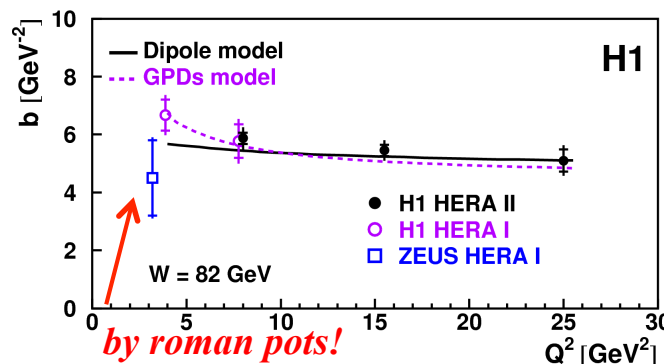
Phase space

- $1.0 < Q^2 < 100 \text{ GeV}^2$
- $10^{-4} < x < 0.1$
- $0.01 < y < 0.85$
- $0 < |t| < 1.5 \text{ GeV}^2$

- Radiative corrections: OFF
- t slope: $B = 5.00$ (constant)
- GPDs evolved at NLO



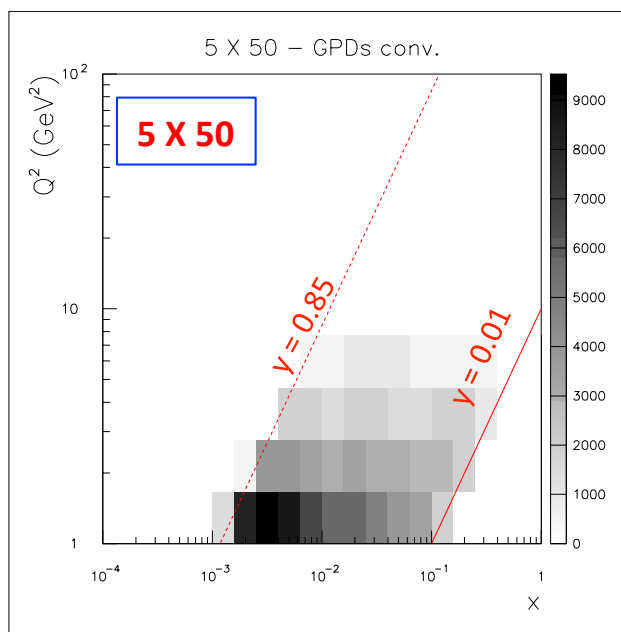
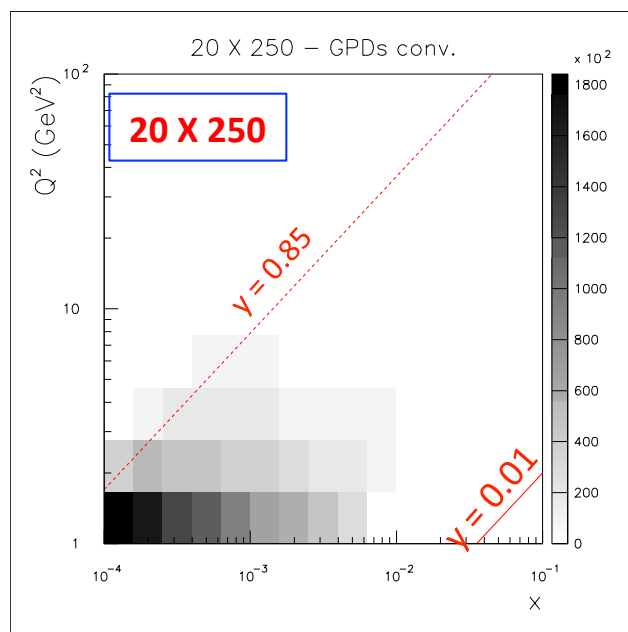
Scanning the phase space...



EIC lumi:
11.6 fb⁻¹/month @ 20x250

- ✧ EIC will provide sufficient luminosity to bin in multi-dimensions
- ✧ wide x and Q^2 range needed to extract GPDs

... we can do a fine binning in Q^2 and W !

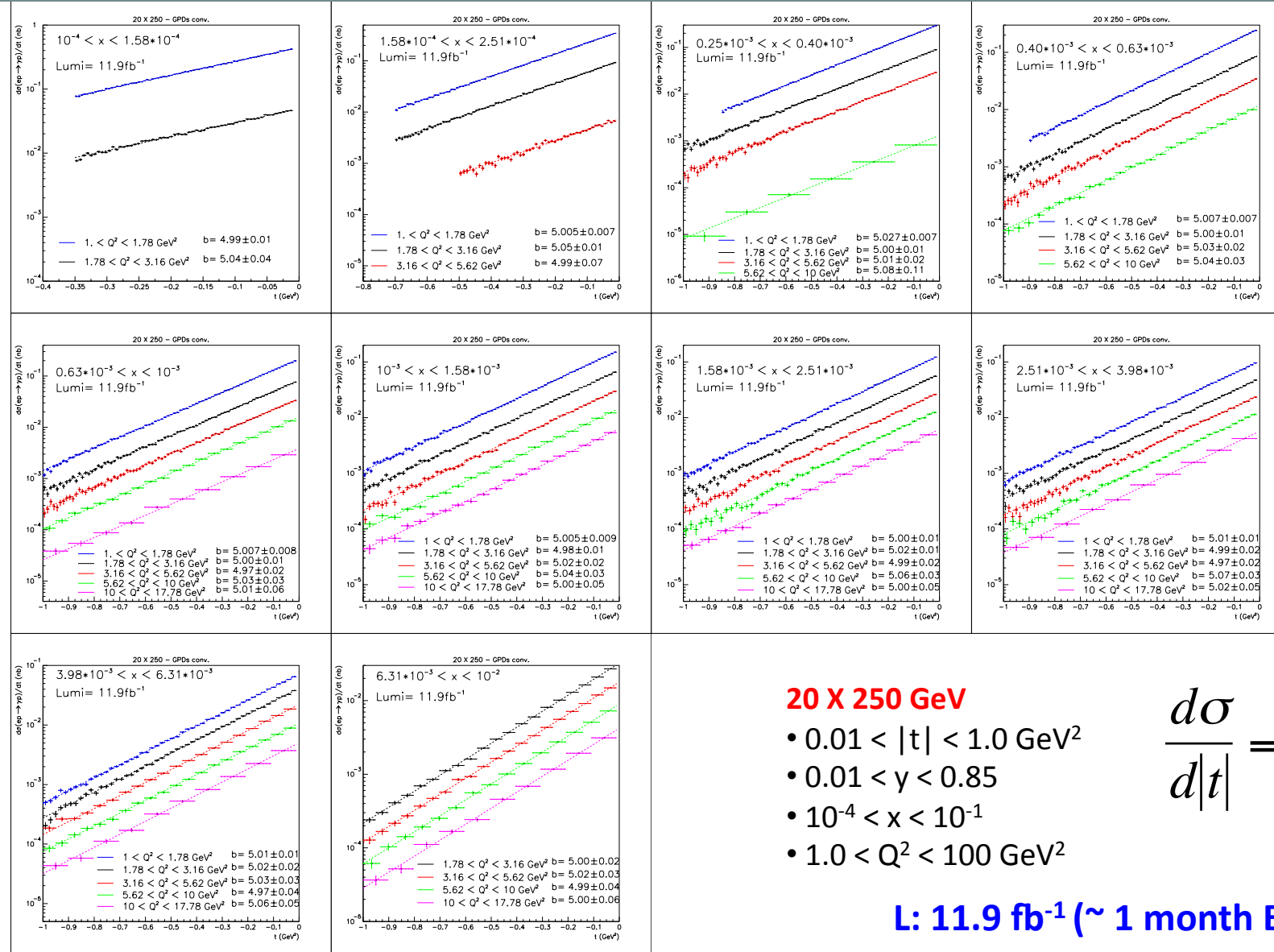


Logarithmic bins:

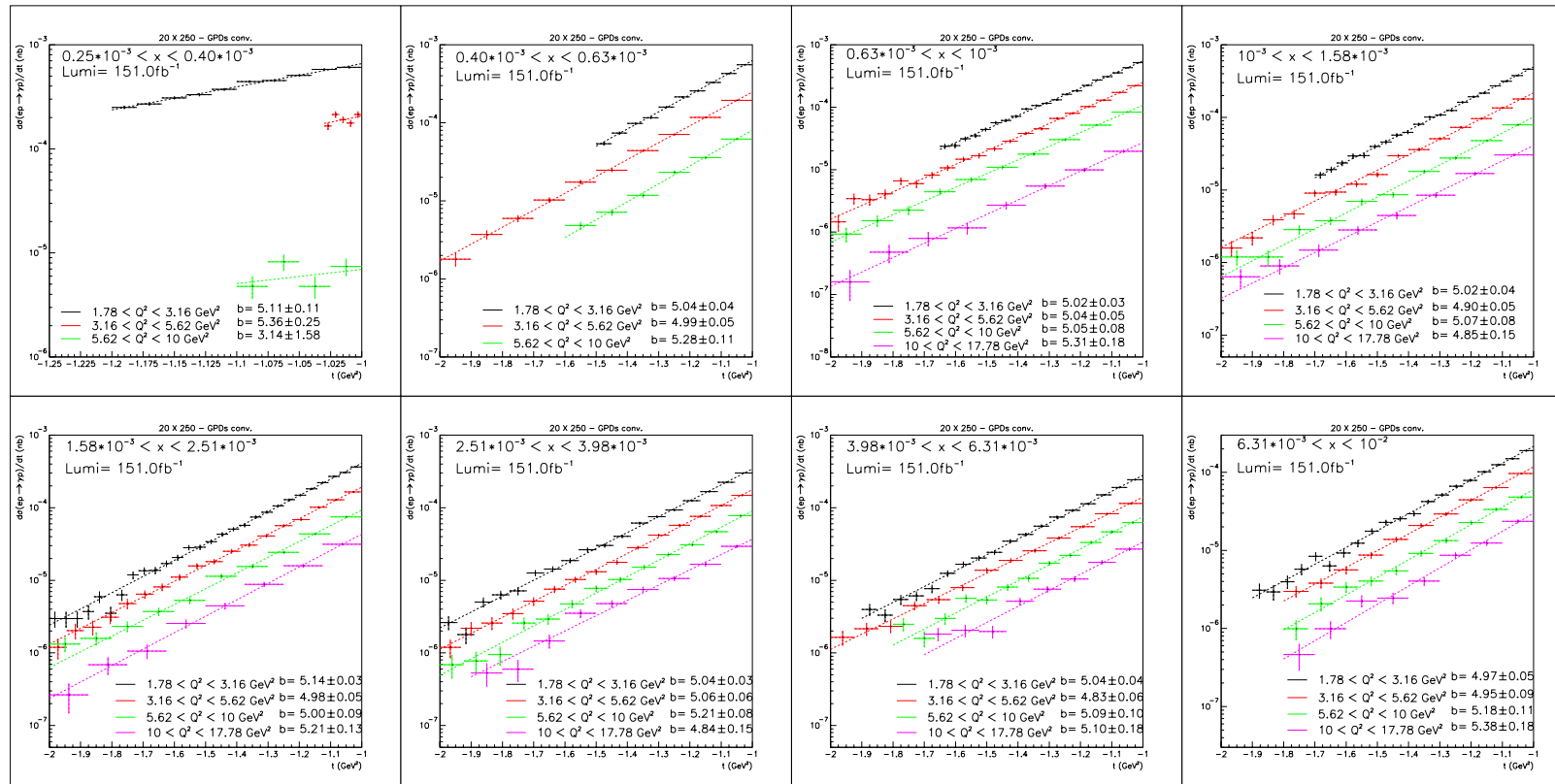
$$1 < Q^2 < 100 \text{ GeV}^2$$

$$10^{-4} < x < 0.1$$

|t|-differential x-sec: low |t|



$|t|$ -differential cross section: high $|t|$



$1.0 < |t| < 2.0 \text{ GeV}^2$

300k DVCS events simulated
L: 151 fb⁻¹ (~ 52 weeks EIC)

eRHIC can provide precise measurement of the $|t|$ -slope even at large $|t|$ values... but this may require years of data taking

|t|-differential cross section

$0.01 < |t| < 1.0 \text{ GeV}^2$

- Precision enormously improved a.r.o. present (mostly below 1%)
- Systematics will dominate!
- Mostly within Roman pots acceptance ($|t| > 0.06 \text{ GeV}^2$), using RP one pays price for less geometrical acceptance ($\sim 20\%$ with STAR simulation of RP) but gains more precision.

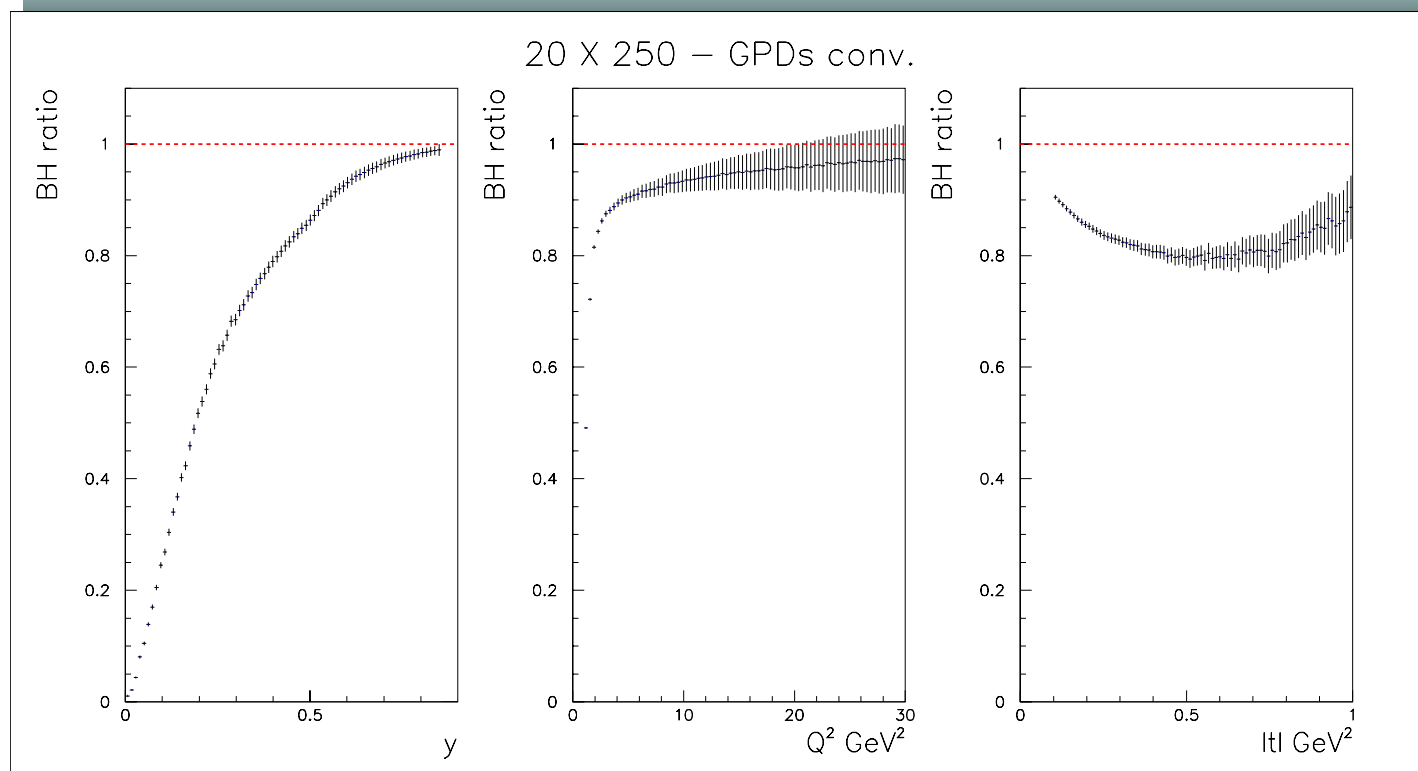
i.e. RP @ ZEUS:

Resolution LPS: $P_t = 5 \text{ MeV} \rightarrow |t| = 10^{-2} P_t$

$1.0 < |t| < 2.0 \text{ GeV}^2$

- Xsec drops drastically
- eRHIC still allows for good binned measurements after years of data taking
- Main detector can be used for measuring $|t|$ from momentum conservation.

Fraction of Bethe-Heitler



$1.0 < Q^2 < 100 \text{ GeV}^2$
 $0.01 < y < 0.85$
 $0.1 < |t| < 1.0 \text{ GeV}^2$

DVCS and BH samples normalized at Lumi

$$\text{frac}(BH) = \frac{BH_{evt}}{BH_{evt} + DVCS_{evt}}$$

BH generated sample much smaller than DVCS one -> error bars

- Proton dissociation not included for both DVCS and BH (but mostly process independent...)
- **BH dominates at large y** (as expected!)
- Part of BH will be removed by DVCS selection criteria for a DVCS enriched sample (interference term not affected)

DVCS: the beam-charge asymmetry

$$|A|^2 = |A_{DVCS}|^2 + |A_{BH}|^2 + \boxed{|A_I|^2} \quad \text{DVCS and BH: identical final state} \rightarrow \text{they Interfere}$$

Interference term: $A_I \propto \text{Re}(A_{DVCS}) + \text{Im}(A_{DVCS})$

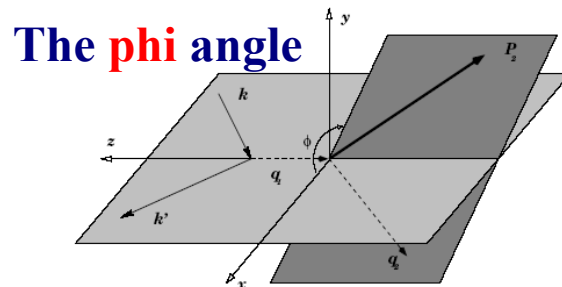
Beam charge asymmetry:
$$A_C = \frac{\frac{d\sigma^+}{d|\phi|} - \frac{d\sigma^-}{d|\phi|}}{\frac{d\sigma^+}{d|\phi|} + \frac{d\sigma^-}{d|\phi|}} = p_1 \cos(\phi) = 2A_{BH} \frac{\text{Re } A_{DVCS}}{|A_{DVCS}|^2 + |A_{BH}|^2} \cos(\phi)$$

|t|-slope: $e^{-b|t|} \Rightarrow \sigma_{DVCS} = |A_{DVCS}|^2 / 16\pi b$

$|A_{BH}|$ is well known

The ratio between the real and imaginary parts of the DVCS amplitude can be extracted:

$$\rho = \frac{\text{Re } A_{DVCS}}{\text{Im } A_{DVCS}}$$



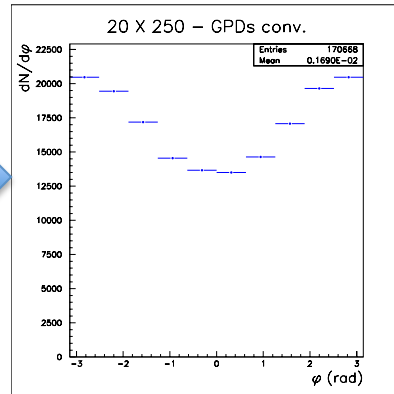
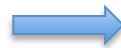
At EIC:

Possible with a positron beam,
thanks to a good tracker coverage

Beam Charge Asymmetry

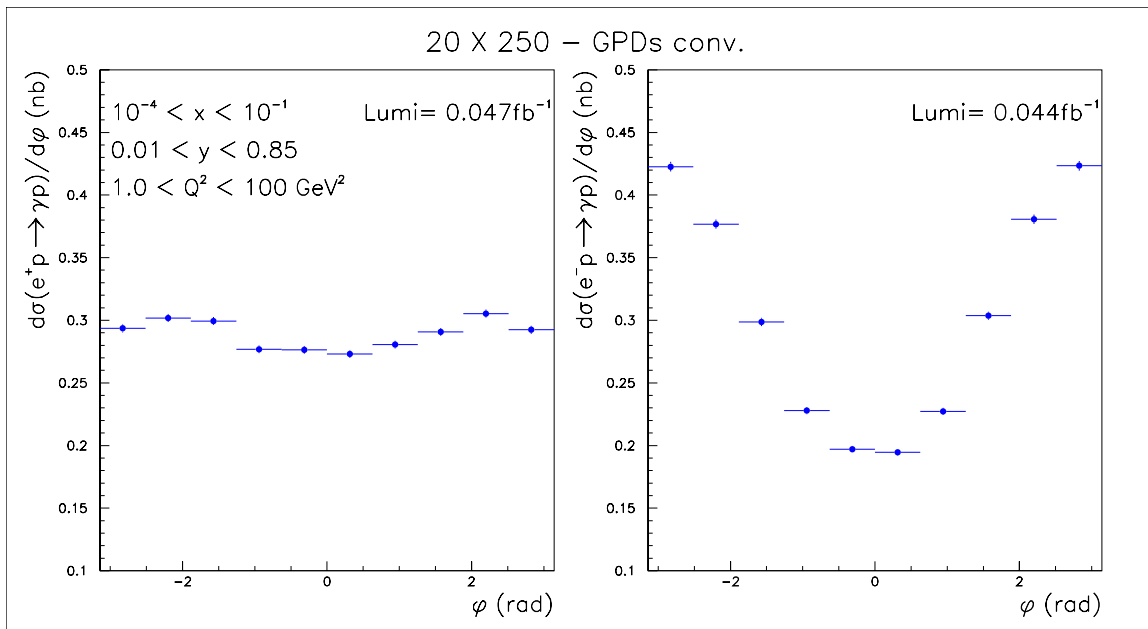
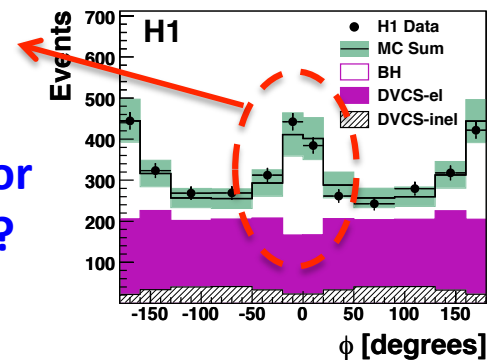
A data sample including DVCS + BH + Int has been generated for the configuration 20 X 250 for electrons and positrons beams separately

Lumi-ele: 44 pb^{-1}
Lumi-pos: 47 pb^{-1}



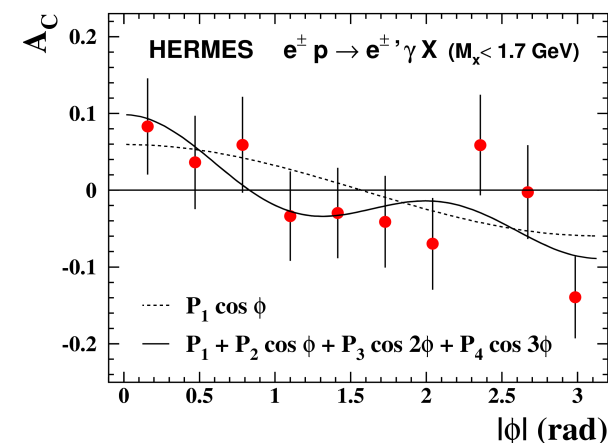
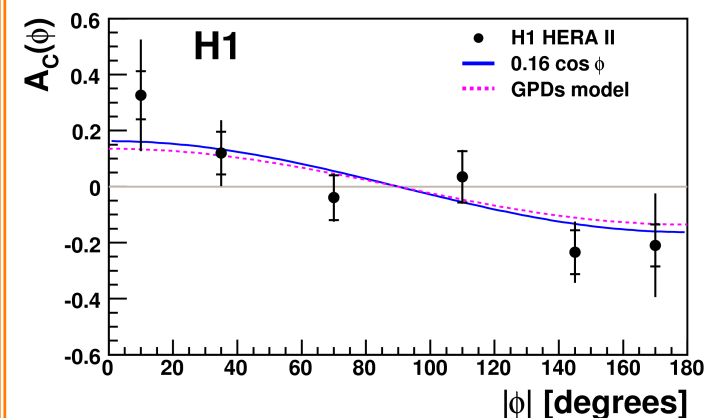
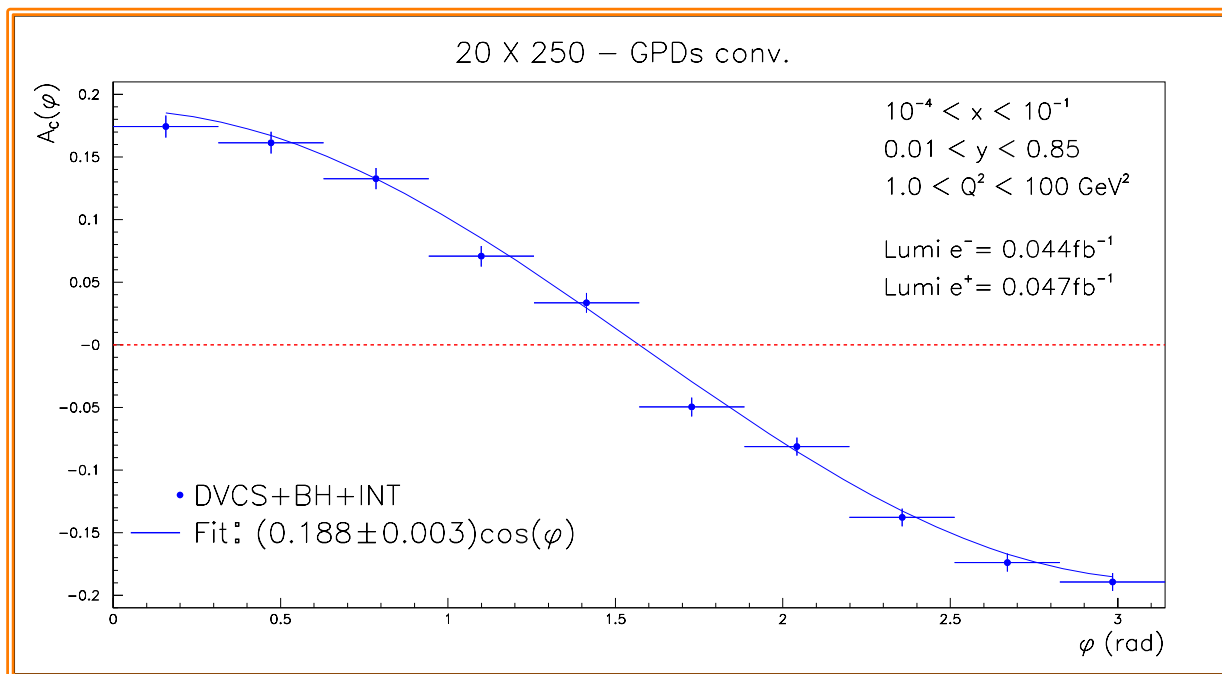
?
Detector
effect?

Investigating...



For both electrons and positrons
the differential xsec vs ϕ has been
extracted

Beam Charge Asymmetry



$$A_C = \frac{\frac{d\sigma^+}{d|\phi|} - \frac{d\sigma^-}{d|\phi|}}{\frac{d\sigma^+}{d|\phi|} + \frac{d\sigma^-}{d|\phi|}} = p_1 \cos(\phi) = 2A_{BH} \frac{\text{Re } A_{DVCS}}{|A_{DVCS}|^2 + |A_{BH}|^2} \cos(\phi)$$

Excellent measurement with a modest beam-time. Accurate measurements in bins of Q^2 and x are possible! (Simulating more samples...)

Summary

- **Uncertainties for low $|t|$ values will be dominated by systematics, the use of RP is convenient**
- **Differential xsec at large $|t|$ values can also be measured with good accuracy, this requires years of data taking. The use of the main detector for measuring $|t|$ from momentum conservation is the best option**
- **BH dominated at large y**
- **BCA can also be measured, it is complementary to the $|t|$ xsec, it required positron beam even with lower lumi**

Outlook:

- ✧ **Running the simulation for 5X50**
- ✧ **Simulation of spin asymmetries**
- ✧ **Use the CFFs from D. Mueller as an input to MILOU**
- ✧ **Simulation of DVCS on nuclei (Tobias stay tuned...)**

Back up

5 X 50

Lumi: 1.2 fb^{-1} (~ 1 week EIC)

$$\frac{d\sigma}{d|t|} = \frac{\# \text{ evt}}{\Delta_{bin} \cdot \mathcal{L}}$$

